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LI-HSÜEH HSÜEH-PAO (ACTA MECHANICA SINICA)

LI-HSÜEH HSÜEH-PAO

(力学学報)

ACTA MECHANICA SINICA

Vol. 3, No. 1, January 1959

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Flow of Underground Water to an Imperfect Well in a Homogeneous Anisotropic Porous Medium

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LI-HSÜEH HSÜEH-PAO

(力学学報)

ACTA MECHANICA SINICA

Vol. 3, No. 3, July 1959

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ABSTRACT

Elastic Stresses and Deformations Produced in a Semi-infinite Elastic Solid by a Point Source of Heat beneath Its Free Surface

For the purpose of solving our problem, we have, first of all, deliberately set up the displacement function

$$\Phi = \frac{1+\nu}{1-\nu} \cdot \frac{\alpha_0 Q}{4\pi\lambda_0} \left(\sqrt{|z-h|^2 + r^2} - \sqrt{(z+h)^2 + r^2}\right) \tag{19}$$

aiming to fulfill the Poisson equation

$$\Delta\Phi \equiv \left(\frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{\partial^2}{\partial z^2}\right)\Phi = \frac{1+\nu}{1-\nu}\alpha_0 T, \tag{10}$$

where the temperature field T, aroused by the point source of heat, amounts to

$$T = \frac{Q}{4\pi\lambda_0}\left(\frac{1}{\sqrt{|z-h|^2 + r^2}} - \frac{1}{\sqrt{(z+h)^2 + r^2}}\right). \tag{17}$$

In order to warrant the unloaded conditions of the free surface of the semi-infinite elastic solid, which, in general, will not always be fulfilled by the sought displacement function Φ, we have resorted to a search for a second displacement function, whose derivation was carried out in another paper by the author entitled "Elastic stresses and deformations produced in a semi-infinite solid by the application of tangential traction to its free surface" (LI-HSÜEH HSÜEH-PAO/ACTA MECHANICA SINICA, Vol. 3, No. 2, 1959, 120).

When we superpose the stresses as well as the displacements corresponding to the two above-mentioned displacement functions, we obtain the

following expressions as the solution to this thermal stress problem:

$$\sigma_z = \bar{\sigma}_z + \bar{\bar{\sigma}}_z = GK\left\{-\frac{2(z-h)^2+r^2}{[|z-h|^2+r^2]^{3/2}} + \frac{2(z+h)^2+r^2}{[(z+h)^2+r^2]^{3/2}}\right\} + 2GKhz\frac{2(z+h)^2-r^2}{[r^2+(z+h)^2]^{5/2}}; \tag{34}$$

$$\begin{aligned}\tau_{rz} = \bar{\tau}_{rz} + \bar{\bar{\tau}}_{rz} = &-GK\left\{\frac{r(z-h)}{[|z-h|^2+r^2]^{3/2}} + \frac{r(z+h)}{[(z+h)^2+r^2]^{3/2}}\right\} - \\ &-2GK\frac{hr}{[r^2+(z+h)^2]^{3/2}} + 6GK\frac{hzr(z+h)}{[r^2+(z+h)^2]^{5/2}};\end{aligned} \tag{35}$$

$$\begin{aligned}\sigma_r = \bar{\sigma}_r + \bar{\bar{\sigma}}_r = &GK\left\{-\frac{(z-h)^2+2r^2}{[|z-h|^2+r^2]^{3/2}} + \frac{(z+h)^2+2r^2}{[(z+h)^2+r^2]^{3/2}}\right\} + 2GK\frac{h(3z+2h)}{[r^2+(z+h)^2]^{3/2}} - \\ &-2GKhz\frac{2(z+h)^2-r^2}{[r^2+(z+h)^2]^{5/2}} - 2GKh\frac{\lambda+2\mu}{(\lambda+\mu)r^2}\left(1-\frac{z+h}{\sqrt{r^2+(z+h)^2}}\right);\end{aligned} \tag{36}$$

$$\begin{aligned}\sigma_\theta = \bar{\sigma}_\theta + \bar{\bar{\sigma}}_\theta = &-GK\left\{\frac{1}{\sqrt{|z-h|^2+r^2}} - \frac{1}{\sqrt{(z+h)^2+r^2}}\right\} - \frac{2GK}{\lambda+\mu}\cdot\frac{h(\mu z-\lambda h)}{[r^2+(z+h)^2]^{3/2}} + \\ &+2GK\frac{\lambda+2\mu}{\lambda+\mu}\cdot\frac{h}{r^2}\left(1-\frac{z+h}{\sqrt{r^2+(z+h)^2}}\right);\end{aligned} \tag{37}$$

$$\begin{aligned}u_r = \bar{u}_r + \bar{\bar{u}}_r = &\frac{K}{2}\left(\frac{r}{\sqrt{|z-h|^2+r^2}} - \frac{r}{\sqrt{(z+h)^2+r^2}}\right) + \\ &+GK\frac{\lambda+2\mu}{\mu(\lambda+\mu)}\cdot\frac{h}{r}\left(1-\frac{z+h}{\sqrt{r^2+(z+h)^2}}\right) - \frac{GK}{\mu}\cdot\frac{hzr}{[r^2+(z+h)^2]^{3/2}};\end{aligned} \tag{38}$$

$$\begin{aligned}u_z = \bar{u}_z + \bar{\bar{u}}_z = &\frac{K}{2}\left(\frac{z-h}{\sqrt{|z-h|^2+r^2}} - \frac{z+h}{\sqrt{(z+h)^2+r^2}}\right) - \\ &-\frac{GK}{\lambda+\mu}\cdot\frac{h}{\sqrt{r^2+(z+h)^2}} - \frac{GK}{\mu}\frac{hz(z+h)}{[r^2+(z+h)^2]^{3/2}}.\end{aligned} \tag{39}$$

All the above expressions for the stresses and the displacements have been numerically evaluated with appropriate data and discussed in detail with accompanying graphs in Figures 1 to 18 (original text). The variations of these expressions representing the complete solution to this thermal elastic boundary value problem are shown by the curves in Figures 19 to 36 (original text).

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LI-HSÜEH HSÜEH-PAO

(力学学報)

ACTA MECHANICA SINICA

Vol. 3, No. 4, October 1959

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Creep of Circular Symmetrical Plates and Cylindrical Shells

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Importance and Possibility of Numerical Evaluation in Aerodynamics

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Experimental Verification of Several Creep Theories by Creep Tests on No. 45 Steel

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ABSTRACTS

Similarity Structure of Vorticity Fluctuation and the Theory of Turbulence

The fluctuation motion in a turbulent flow is considered to consist in the random motion of vortices governed by the equations of turbulent vorticity fluctuation derived by taking the curl of the equations of velocity fluctuation. In the downward-moving system at mean velocity of the fluid, the vortices in the fluid are assumed to have similarity structure. In other words, according to the present theory, dynamically similar solutions are chosen for the equations of vorticity fluctuation in a moving system of reference.

Special problems are solved for turbulent flows limited by channel-like boundaries, along a semi-infinite plate and through a circular pipe, and, for free turbulence, in the two-dimensional and axially symmetrical wakes. It is shown that by neglecting the terms for the degree of viscosity in the equations of vorticity fluctuation in the moving system, the dynamical similarity condition leads to von Karman's well-known similarity regulations for boundary-limited flows in the central region of the wakes; while in the outer region within the wake interior, where the effect of viscosity cannot be ignored, the similarity condition yields the experimentally established relation that the Reynolds apparent shearing stress component is proportional to the transversal gradient of the mean flow velocity.

The requirement that the turbulent vorticity structure should have dynamical similarity leads to the conclusion that all the components of the Reynolds stress are mutually proportional to each other in the flow region where a definite type of similarity prevails. This theoretical result has experimental verification both in the boundary-limited flows and in the two-dimensional wake. The velocity correlations between two distinct points should also be independent of their position within the flow region having the same type of similarity, so long as the relative displacement between the two points remains the same. This also agrees qualitatively with the observations available.

The application of the condition of dynamical similarity gives us a length Λ, characterizing the size of vortices which compose the turbulent fluctuation. In the Karman type of similarity, Λ depends only upon the space derivatives of the mean velocity and is independent of the fluid viscosity, while Λ of the other type of vortices in the outer part of the wake interior is dependent upon the coefficient of viscosity. The size of the latter kind is much smaller than the former. These two kinds of vortices in turbulent motion have long been anticipated in theoretical investigations of turbulence.

In view of the fact that the condition of dynamical similarity can only be applied within a definite flow region and that not only in different flow problems but also in different flow regions of the same problem there are different similarity solutions as in the central and outer regions of the wake interior, we can see the limited nature of the application of the similarity concept in the turbulence theory.

Hence more rigorous solutions of the original vorticity fluctuation equation should be sought in order to connect the different types of similarity solutions present, for instance, in the wake problem.

The non-dimensional equations of vorticity fluctuation are still non-linear after the similarity transformation. It is difficult to obtain their solutions and (based upon them) to build the velocity correlation functions between two distinct points by the space average method. Since Taylor's scale of microturbulence λ is defined by a double velocity correlation, here again there is difficulty in obtaining the accurate relation between λ and the present scale of turbulent vorticity Λ.

Besides dealing with the heat conductivity problem in turbulent flows, the paper also gives applications for heated wakes. The theoretical result for the two-dimensional heated wake agrees with the existing experimental measurement.

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Experimental Verification of Several Creep Theories

by Creep Tests on No. 45 Steel

Utilizing creep curves obtained for No. 45 steel under 500° C and different stresses, several typical creep theories, i.e., strain hardening theory-- $f(\sigma,\dot{\epsilon}_p,\epsilon_p)=0$, time hardening theory-- $f(\sigma,\dot{\epsilon}_p,t)=0$, and plastic hereditary theory-- $\varphi(\epsilon)=\sigma(t)+\int_0^t K(t-\tau)\sigma(\tau)d\tau$, are verified. Results are analyzed and simple methods for checking these theories are given.

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LI-HSÜEH HSÜEH-PAO

(力学学報)

ACTA MECHANICA SINICA

Vol. 4, No. 1, January 1960

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Efficiency of Water Wheels in Hydrodynamics

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Determination by a Direct Method of Stresses and Displacements Produced in a Semi-infinite Elastic Solid by a Fixed Point Source of Heat on Its Surface

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ABSTRACTS

Free Edge Rectangular Plates on Elastic Foundations

This paper is a generalization of an article by H. Hapel entitled "Über das Gleichgewicht von elastischen Platten unter einer Einzellast" (Mathematische Zeitschrift, 6, 1920). It differs from the article in four respects:

(1) Both symmetrical and asymmetrical loadings are discussed in detail.

(2) The origin of the coordinates is placed at the corner of the plate instead of at the center. In this way the functions U and V and their integrals are considerably simplified.

(3) Both isotropic and orthotropic plates are treated.

(4) Both the Ritz and the Galerkin method of variation are used to solve the problem.

In the paper the variation equations are written in standard form and the values of the functions U and V and their second derivatives at 11×11 points are tabulated. Once the dimensions a and b, the rigidity D of the plate, the modulus k of the foundation, and the concentrated loads P are known, the reader may calculate the deflections of and the moments in the plate by direct application of these equations.

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Effect of Earthquakes on Dams (1)

In this paper, the results of a model test of earthquake effect on dams are presented.

The experimentation consists of measuring the strains and displacements at various points on the surface of the model when it is suddenly set into vibration by a horizontal impulse applied to its base. The model is fixed to a rigid table suspended on cables, and the impulse is calibrated so that a known amount of momentum is transferred to the table by impact of the pendulum. The duration of impact is made much shorter than the second natural period of vibration of the model. The swing of the table after impact, being of very low frequency, does not cause any appreciable additional distortion to the model and can be neglected.

Insofar as the model may be regarded as a linear elastic system, if we denote the stress (or displacement) measured at any point by $K(t)$, then for arbitrary ground acceleration $\ddot{Z}(t)$, such as produced by an earthquake, the stress (or displacement) at the same point may be evaluated by means of Duhamel's integral, i.e.,

$$\sigma(t) = \int_0^t K(t-\tau)\,\ddot{Z}(\tau)\,d\tau.$$

The model is made of rubber. Bonded resistance wire gauges are used for the measurement of strain. The strain gauges, because of their high rigidity in comparison with that of rubber, alter in a significant way the local strain distribution of the model, so that the apparent strain readings taken by the ordinary method do not give the actual strains which would be produced when no strain gauges were used.

However, it is found by our experiment that a definite ratio exists between the apparent and actual strains.

The results of the experiment are given in Figures 3 to 8 (original text).

$K(t)$ can be resolved into various components of free vibration, each component being of the type $e^{-n_i\omega_i t}\sin\sqrt{1-n_i^2}\,\omega_i t$. Conversion of the results of the model experiment to the prototype is direct provided one makes certain modifications to account for the difference in damping coefficients and neglects the difference in Poisson's ratios. Making use of this fact, the stresses are computed by means of Duhamel's integrals, for which an actual acceleration seismogram is used. Similarly, use is made of published strong earthquake spectra to find the upper bounds of stresses which may possibly occur during strong earthquakes.

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Efficiency of Water Wheels in Hydrodynamics

Among the various small types of low water-head power systems or hydroelectric power stations, the one operated by water wheels is the most suitable for the present rural areas of China. The use of water wheels in these facilities is more efficient than any type of water turbine, especially when the available water-head is less than two meters.

In this paper the head losses in the "middle-push" type water wheel are analyzed, their magnitudes estimated and the similarity law derived. It is pointed out that the kinetic energy flowing out from the water wheel can be recovered by a well-designed open channel.

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LI-HSÜEH HSÜEH-PAO

(力学学報)

ACTA MECHANICA SINICA

Vol. 4, No. 2, April 1960

CONTENTS

ABSTRACT

Design for the Runner Vanes of Francis Water Turbines (1)

Under Vallander's assumption the stream surfaces in a Francis water turbine remain the same with or without the runner vanes. The equation governing the flow in a thin sheet between two adjacent stream surfaces is

$$\frac{\partial^2\phi}{\partial u^2}+\frac{\partial^2\phi}{\partial z^2}+\frac{1}{h}\frac{\partial h}{\partial z}\frac{\partial\phi}{\partial z}=0$$

or

$$\frac{\partial^2\psi}{\partial u^2}+\frac{\partial^2\psi}{\partial z^2}-\frac{1}{h}\frac{\partial h}{\partial z}\frac{\partial\psi}{\partial z}=0,$$

where ϕ and ψ denote the velocity potential and the stream function, u and z are the transformed coordinates and h is the thickness of the thin stream surface sheet under consideration.

By the transformations $\phi=\sqrt{h}\,\Phi$ and $\psi=\frac{1}{\sqrt{h}}\Psi$, the pair of equations is reduced to

$$\nabla^2\Phi=0 \text{ and } \nabla^2\Psi=0,$$

if $\frac{d}{dz}\left(\frac{1}{h}\frac{dh}{dz}\right)$ and $\left(\frac{1}{h}\frac{dh}{dz}\right)^2$ are small by comparison with the square of the number of runner vanes.

The flow around the vanes in a thin stream surface sheet was also treated by Vallander and Kiselev; however, the relation between the flows in two adjacent stream surface sheets remains as yet unknown. In this paper the same relation is adopted to connect the flows in adjacent sheets as in Bauersfeld-Voznesensky's two dimensional theory, that is, the circulation along the contour between any two meridianal planes and

outside of the runner vane is constant.

The solution is based on the method of singularities. At the end of the paper the vortex distribution function is discussed. It is found that the addition of a term corresponding to the flow about a flat plate results in a definite angle of attack and thereby increases load near the leading edge of a vane, which may be desirable in certain cases. But the distribution function needs to be further improved for a good design.

It is worthy of note that the present solution is also applicable to the case where h is not constant and small as assumed in Kiselev's method, and that it would avoid the lengthy computation of Vallander's method, although Vallander's solution is more accurate.

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